

# Genetic and environmental factors in the determination of general cognitive abilities: a twin study

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■ **ABSTRACT** : The present investigation of twin study elucidated the contribution of genetic and environment to a wide range of general cognitive abilities. To conduct twin study 100 pairs of twins from two districts, namely: Bhiwani (n = 90) and Hisar (n = 110) of Haryana State, genetic and environmental influences were assessed in twin study design. The cognitive abilities of twins were measured using the Wechsler Intelligence Scale for Children (WISC-R). Home Observation for Measurement of the Environment (HOME) Inventory was taken to examine the home environment of twins. Heritability estimate was used to analyze the genes contributing to shape the cognitive abilities of twins. The result of heritability estimates revealed that the heritability estimates of general cognitive abilities namely: information (62%), similarities (57%), vocabulary (60%) and comprehension (55%) in Bhiwani district and in Hisar district, the heritability estimates were 58 per cent, 55 per cent, 56 per cent and 51 per cent for information, similarities, vocabulary and comprehension general cognitive abilities, respectively. The findings clearly elucidated that the general cognitive abilities were more influenced by genetic background than the environmental factors. The paternal involvement and physical environment were strongly associated with general cognitive abilities of twins. The monozygotic twins were more correlated in their general cognitive abilities than the dizygotic twins.

■ **KEY WORDS**: Genetic, Heredity, Environment, Monozygotic twins, Dizygotic twins

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The advancement in researches of neuroscience has sharpened focus on the importance of the classical twin study in understanding cognitive function (Van Dongen *et al.*, 2012). The twin births symbolize fascinating experiment of nature that provide a deep understanding about variations in general cognitive abilities of twins contributed to genetic and environmental variation (Iacono *et al.*, 2018). Heritability may be

defined as the proportion of variation in cognitive abilities that arises from genetic influences. Haworth *et al.* (2010) revealed that heritability and general cognitive abilities increased slowly throughout the lifetime. The reason was attributed to a regular increase in active genotype-environment covariance. They also concluded that the heritability and general cognitive ability mainly increased linearly from childhood to young adulthood.

The genetic and environmental influences on cognition of twins and sibling pairs are important from infancy to adolescence. The genes affect the cognitive abilities of twins that develop into the first decade of life and increase over time. The early literacy and education played a vital role in shaping the cognitive abilities of twins during the first decade of life (Briley *et al.*, 2013). According to monozygotic and dizygotic twin studies cognitive levels and cognitive abilities are influenced by individual's genetic background (McGue and Christensen, 2013).

The gene-environment interaction (GxE) refers to the genetic sensitivity or susceptibility to environments. It is important to note that GxE is usually limited to statistical interactions, *i.e.*, the effect of genes depends on the environment and/or the effect of the environment depends on the genotype. The degree of genetic variation increases gradually from early childhood to adulthood but environmental variation decreases (Tucker-Drob *et al.*, 2013). Further, there was evidence that genetic effects on patterns of brain change over time and the magnitude of relative genetic versus environmental influences may increase over the course of development (Anokhin *et al.*, 2017).

The individual differences in general cognitive abilities during early years were genetically and environmentally influenced, which in turn further differentiated individuals by general cognitive abilities (Beam *et al.*, 2015). The genetic factors influenced level of general cognitive abilities and specific cognitive abilities changed differently with age (Lyons *et al.*, 2017). The cognitive abilities of twins were heritable and observed that the genetic and environmental influences on different developmental patterns of general cognitive abilities of twins from the age group 7 to 12 years (Zheng *et al.*, 2018). Spengler *et al.* (2018) investigated that genetic and environmental effects on cognitive abilities of twins in the age of 7-14 years and reported that general cognitive ability and nonverbal ability indicated no significant interaction with parental education, while verbal abilities showed a significant interaction with parental education. Jancke (2018) supported that many brain and cognitive features were modulated by environment, culture, and practice. It was also observed that cognitive abilities of twins affected by different parenting styles and family's cultural values (Huang *et al.*, 2017).

## ■ RESEARCH METHODS

### Study design:

The aim of twin study was to find out genetic and environmental impact on general cognitive abilities. The study was carried out in two districts namely: Bhiwani (n = 90) and Hisar (n = 110) of Haryana state. To assess the general cognitive abilities of twins, total 100 pairs of twins were selected from two districts with the age group 6 to 8 years.

### Data collection:

The mode of data was collected by assessment, interview, observation and questionnaire method from the twins and their parents to gather information.

### Tool:

The cognition of twins was examined by The WISC-R (Wechsler, 1974) and it is applicable on normal and abnormal children with both sexes and any socio-economic status of children's family. The general cognitive subsets included information, similarities, vocabulary and comprehension. The home environment of twins was analysed by HOME inventory (Bradley *et al.*, 1988) and it analysed the social, emotional and cognitive support provide by family members to their children.

### Statistical analysis:

The statistical analysis performed in software SPSS (Statistical Package for the Social Sciences). Mean, Standard Deviation, z-test, Chi square and heritable estimate were used to meet the objectives of the study. Heritability estimates ( $h^2$ ) were calculated by the following formula given by Falconer (1960),  $h^2 = 2(RMz - RDz)$  where,  $h^2$  is the heritability estimate, RMz is the correlation co-efficient for monozygotic twin pairs and RDz is the correlation co-efficient for dizygotic twins. Correlation co-efficient was used to find the correlation between the intellectual abilities of twins.

## ■ RESEARCH FINDINGS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

### General cognitive abilities of monozygotic and dizygotic twins:

Table 1 revealed highly significant differences in

| General cognitive abilities | Monozygotic                 |                           | Z Value | Dizygotic                   |                           | Z Value |
|-----------------------------|-----------------------------|---------------------------|---------|-----------------------------|---------------------------|---------|
|                             | Bhiwani (n = 62)<br>Mean±SD | Hisar (n = 78)<br>Mean±SD |         | Bhiwani (n = 28)<br>Mean±SD | Hisar (n = 32)<br>Mean±SD |         |
| Information                 | 6.15±2.98                   | 5.77±2.28                 | 0.83    | 6.68±2.51                   | 5.22±2.18                 | 2.39*   |
| Similarities                | 2.55±2.05                   | 1.81±1.64                 | 2.31*   | 3.00±2.24                   | 1.56±1.29                 | 2.99**  |
| Vocabulary                  | 10.90±4.12                  | 10.09±4.64                | 1.09    | 11.39±3.82                  | 10.38±4.51                | 0.94    |
| Comprehension               | 7.27±2.60                   | 6.23±2.53                 | 2.38*   | 8.07±2.77                   | 6.25±2.64                 | 2.60**  |

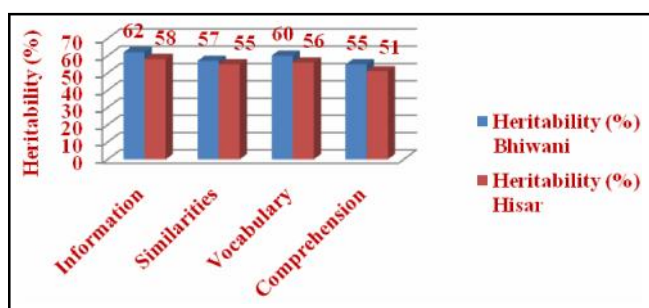
\* and \*\* indicate significance of values at P=0.05 and 0.01, respectively

mean values for similarities ( $Z = 2.99^{**}$ ) and comprehension ( $Z = 2.60^{**}$ ) general cognitive abilities in dizygotic twins. The significant differences were also found between Bhiwani and Hisar districts for monozygotic twins on dimensions of cognitive, namely, similarities ( $Z = 2.31^*$ ), comprehension ( $Z = 2.38^*$ ), while for dizygotic twins on information ( $Z = 2.39^*$ ) but non-significant differences were found for remaining vocabulary over two districts. Twins at Bhiwani districts performed better than Hisar district for all general cognitive abilities.

#### Heritability estimates for cognitive abilities of twins over districts:

The Table 2 portrait regarding the heritability estimates for cognitive abilities of twins in both districts namely: Bhiwani and Hisar. The heritability estimates for cognitive abilities namely: Information (62%), Similarities (57%), Vocabulary (60%) and

| General cognitive abilities | Heritability (%) |       |
|-----------------------------|------------------|-------|
|                             | Bhiwani          | Hisar |
| Information                 | 62               | 58    |
| Similarities                | 57               | 55    |
| Vocabulary                  | 60               | 56    |
| Comprehension               | 55               | 51    |



**Fig. 1 : Heritability estimates for general cognitive abilities of twins over districts**

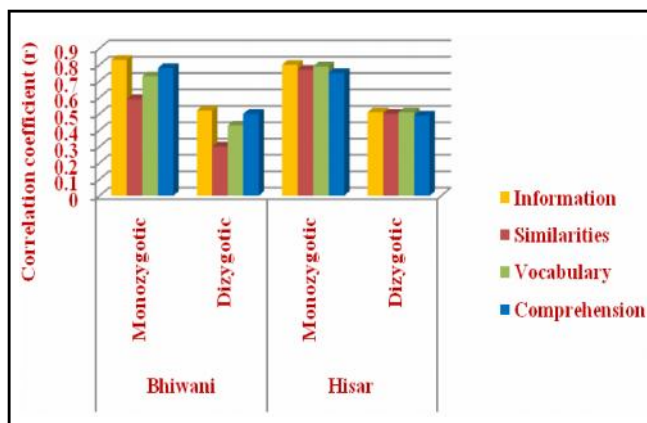
Comprehension (55%) in Bhiwani district. The data clearly indicated that the remaining 38 per cent variance in information cognitive abilities were due to environmental factors. Further the data portrait that 43 per cent, 40 per cent and 45 per cent variance in similarities, vocabulary and comprehension, respectively were due to environmental circumstances. In Hisar district, the heritability estimates for information, similarities, vocabulary and comprehension were 58 per cent, 55 per cent, 56 per cent and 51 per cent, respectively. The clearly indicated that remaining 42 per cent variance in information was due to environmental factors and 45 per cent, 44 per cent and 49 per cent in similarities, vocabulary and comprehension, respectively contributed to environmental situations. The heritability estimates clearly revealed that more genetic influence on information cognitive abilities followed by vocabulary, similarities and comprehension general cognitive abilities in Bhiwani district. In Hisar district, the heritability estimates accounted for information was highest (58%) followed by vocabulary that was 56 per cent, similarities that was 55 per cent and heritability was lowest for comprehension (51%). The genetic influence was more on information followed by vocabulary, similarities and comprehension general cognitive abilities in Hisar district.

#### Correlation co-efficient among monozygotic twins and dizygotic twins for general cognitive abilities in both districts:

The Table 3 provided the information regarding the correlation co-efficient among monozygotic and dizygotic twins for general cognitive abilities in Bhiwani and Hisar district. The data in Table 3 portrait that the correlation co-efficient among monozygotic twins for general cognitive abilities namely: information, similarities, vocabulary and comprehension was  $r=0.83$ ,  $r=0.59$ ,  $r=0.73$  and  $r=0.78$ , respectively in Bhiwani district. Among dizygotic twins, the correlation co-efficient for

**Table 3 : Correlation co-efficient among monozygotic twins and dizygotic twins for general cognitive abilities in both districts**

| General cognitive abilities | Correlation co-efficient (r) |           |             |           |
|-----------------------------|------------------------------|-----------|-------------|-----------|
|                             | Bhiwani                      |           | Hisar       |           |
|                             | Monozygotic                  | Dizygotic | Monozygotic | Dizygotic |
| Information                 | 0.83                         | 0.52      | 0.80        | 0.51      |
| Similarities                | 0.59                         | 0.30      | 0.77        | 0.50      |
| Vocabulary                  | 0.73                         | 0.43      | 0.79        | 0.51      |
| Comprehension               | 0.78                         | 0.50      | 0.75        | 0.49      |



**Fig. 2 : Correlation co-efficient among twins for general cognitive abilities in both districts**

information (r=0.52), similarities (r=0.30), vocabulary (r=0.43) and comprehension (r=0.50) in Bhiwani district. Further the correlation co-efficient among monozygotic twins was for general cognitive abilities namely: information (0.80), similarities (r=0.77), vocabulary (r=0.79) and comprehension (r=0.75) in Hisar district. Among dizygotic twins, the correlation coefficient was for information (r=0.51), similarities (r=0.50), vocabulary (r=0.51) and comprehension (r=0.49) in Hisar district. The data clearly indicated that monozygotic twins were more correlated with each other in all general cognitive abilities as compared to dizygotic twins in both Bhiwani and Hisar district.

**Associations of general cognitive abilities with home environment in Hisar district:**

Table 4 revealed that the general cognitive abilities of twins were associated with dimensions of home environment, namely, paternal involvement ( $\chi^2=6.49^*$ ), aspects of the physical environment ( $\chi^2=4.77^*$ ).

**Associations of cognitive abilities with home environment in Bhiwani district:**

Table 5 revealed that the cognitive abilities of twins

**Table 4 : Associations of general cognitive abilities with home environment in Hisar district**

| Home environment                           | General cognitive abilities |      |       | $\chi^2$ |
|--|-----------------------------|------|-------|----------|
|  | Low                         | High | Total |          |
| <b>Paternal involvement</b>                |                             |      |       |          |
| Below average                              | 43                          | 5    | 45    | 6.49*    |
| Above average                              | 43                          | 19   | 65    |          |
| Total                                      | 86                          | 24   | 110   |          |
| <b>Aspects of the physical environment</b> |                             |      |       |          |
| Below average                              | 29                          | 14   | 43    | 4.77*    |
| Above average                              | 57                          | 10   | 67    |          |
| Total                                      | 86                          | 24   | 110   |          |

\*indicates significance of value at P=0.05

**Table 5 : Associations of general cognitive abilities with home environment in Bhiwani district**

| Home environment                           | General cognitive abilities |      |       | $\chi^2$ |
|--|-----------------------------|------|-------|----------|
|  | Low                         | High | Total |          |
| <b>Paternal involvement</b>                |                             |      |       |          |
| Below average                              | 44                          | 16   | 60    | 4.84*    |
| Above average                              | 12                          | 18   | 30    |          |
| Total                                      | 56                          | 34   | 90    |          |
| <b>Aspects of the physical environment</b> |                             |      |       |          |
| Below average                              | 30                          | 11   | 41    | 9.20*    |
| Above average                              | 26                          | 23   | 49    |          |
| Total                                      | 56                          | 34   | 90    |          |

\*indicates significance of value at P=0.05

were associated with dimensions of home environment, namely, paternal involvement ( $\chi^2=4.84^*$ ), and aspects of the physical environment ( $\chi^2=9.20^*$ ), at Bhiwani district.

The heritability estimates of general cognitive abilities indicated that the general cognitive abilities were more influenced by genetic factors than the environmental circumstances. Panizzon *et al.* (2014) indicated that general cognitive abilities were highly heritable (86%) and genetics affected the specific cognitive domains. Johnson *et al.* (2011) analyzed the environment and heritability estimates of cognitive abilities and found that 30% variations in cognitive abilities was due to environmental factors and 70% variations due to genetic factors. Van Soelen *et al.* (2010) found that the heritability of general cognitive abilities increased during the transition from childhood to adolescence.

Vernon *et al.* (2011) studied that fraternal twins, or dizygotic twins, shared exactly half their genes with each other. They were not as optimal as identical twins for make out the degrees of genetic influence, but they were a very good basis for comparison for identical twins. The monozygotic twins were more correlated than dizygotic twins in general cognitive abilities.

The result from Table 4 and 5 revealed that aspects of home environment namely paternal involvement and aspects of the physical environment were associated with general cognitive abilities of twins in both Bhiwani and Hisar district. The similar findings supported the result that the early environment are associated with twins' cognitive development and may be more strongly associated with their general cognitive abilities. They also suggested that the level of parental education and the amount of cognitive stimulation from parents had a greater influence on twins' general cognitive abilities Peyre *et al.* (2016). In early childhood one of the main factors that affecting child cognitive development was the family environment, which included both care and stimulation provided to children by the caregivers, and the socio-economic status and physical environment of the family Ronfani *et al.* (2015).

Fergusona *et al.* (2013) reviewed significant effects of the physical environment such as toxins, pollutants, noise, crowding, housing, school and neighbourhood quality on children's cognitive development and suggested that the physical environment experienced by children impacted their cognitive development across the

lifespan, from the prenatal period through adulthood. These results was also supported by Biedinger (2011) who stated that home environment was determined by the availability of stimulating materials (e.g., books, toys, helping teacher), and also through joint time (e.g., attending the library or the museum) all these stimulating resources responsible for the cognitive development of twins.

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